8 November 2010

The Administrator
Engineering Heritage Australia
Engineers Australia
Engineering House
11 National Circuit
BARTON ACT 2600

Dear Sir,

HERITAGE AWARD NOMINATION – REDCLIFFE MINIMUM ENERGY LOSS CULVERT

It is with pleasure that the above project is nominated to be awarded an Engineering Heritage National Landmark.

The structure is located at the inlet to Moreton Bay on Humpybong Creek.

The owner has been advised of this nomination and a letter of agreement is attached in Appendix D.

Regards,

ANDREW BARNES
Chair of Divisional EHA QLD

CONSULT AUSTRALIA
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Nomination of the

REDCLIFFE MINIMUM ENERGY LOSS CULVERT

for recognition as a

NATIONAL ENGINEERING HERITAGE LANDMARK

UNDER THE AUSTRALIAN HISTORIC ENGINEERING PLAQUING PROGRAM

By Anthony Carey
EHA (QLD Panel)

18 May 2009

BASIC DATA:

Item Name:	Redcliffe Minimum Energy Loss Culvert
Other/ Former Names:	Redcliffe storm waterway System Humpybong Creek
Location:	At the inlet Humpbong Creek converges into the structure which flows beneath the town centre and discharges, at the outlet, into Central Moreton Bay.
Address:	Area bounded by Sutton St, Irene St and Redcliffe Parade.
Suburb/ Nearest Town:	Redcliffe
State:	QLD
Local Govt Area:	Moreton Bay Regional Council
Owner:	Moreton Bay Regional Council
Current Use:	Natural creek and storm waterway system that drains into Central Moreton Bay.
Former Uses:	Refer to 'Current Use'.
Designer:	Professor Gordon McKay, University of Queensland (Brisbane).
Maker/ Builder:	Redcliffe City Council (now part of Moreton Bay Regional Council).
Year Started:	Very late 1950s. **Year Completed:** 1961 (Cottman et. al., 1990).
Physical Description:	The Redcliffe Minimum Energy Loss Culvert is a drainage corridor for the tributaries of the Humpybong Creek Catchment to flow out into Central Moreton Bay. The concrete lined structure has a 21m long minimum energy loss (MEL) weir acting as the culvert drop inlet and retains an ornamental lake. This is set 0.8m below the highest acceptable flood level. Concrete lined chute walls and a fan inlet converge into a 137m long rectangular culvert which passes beneath a shopping center carpark. The throat of the culvert is 5.5m wide by 2.5m deep with a depressed bed profile that is set 1.1m below the straight grade from inlet weir crest to outlet lip. The outlet lip is also fan shaped with a 30m long lip set at 0.3m lower than the inlet lip with a combined distance from inlet to outlet of 210m. Each of these components equate to a structure capable of achieving a design flow of 26 cumecs concentrated to a flow of 4.7m3/s per m, with a critical velocity of 3.6m/s and critical depth of 1.3m.
Physical Condition:	The condition of the Redcliffe MEL Culvert remains the same as was after its construction almost 50 years ago. The design philosophy of achieving near critical flow throughout the structure reduces the scouring effects of turbulent flow meaning the concrete lining has required little in the way of repairs over its lifetime.
Modifications/ Dates:	No major modifications to the structure have been documented in the citied research material used in the preparation of this submission. A recent widening of the footpath over the outlet has not affected the hydraulics of the structure. The surrounding landscape however has undergone a transformation due to the reclamation of land in the town center by filling, made possible by the

channeling of the flow into a corridor of reduced width. This land is currently being used for commercial purposes, intersections and car parks.

Historical Notes:

The majority of modern day hydraulic engineering structures remain largely the same as the ancient designs used 3000 years ago. The culvert, which dates back to the times of the ancient European cities of the Minoans and Etruscans, is a key example of this. The shortfalls of its design that were experienced in those times can still be seen as characteristic of the modern day structures, the most significant of these being the flooding associated with upstream afflux (the technical term for the increased water level upstream of a conventional culvert).

Flooding problems faced by the South East Queensland resort community of Redcliffe in the later 1950s led to the conception of the minimum energy loss culvert. Like many landscapes on the Australian east coast, the Humpybong Creek Catchment is characterised by events of torrential rain and particularly low gradients to its ocean outlet. The local authority required that a storm waterway system be designed to deck the wide, marshy, smelly depression that linked the catchment's tributaries with the outlet to Central Moreton Bay. It was required that the solution be as economical as possible by avoiding the construction costs associated with constructing a wide bridge over a conventionally designed culvert system.

The engineering challenge that presented itself became the brainchild of Dr Gordon R. McKay of the University of Queensland. McKay envisioned a structure that would channel the flow of a flood event into a narrow throat with minimum energy loss and hence minimum rise in water level upstream (afflux).

It is always interesting to know how new engineering ideas evolve. McKay's mother was a German and on the completion of his PhD in the UK he spent months in the hydraulic laboratory of the Technischen Hochschule (i.e. University) of Karslruhe in Germany. The laboratory was directed by the then world famous Professor Dr.-Ing. Theodore Rehbock. The major claim to fame of the Karlsruhe laboratory was their skill in making and testing scale hydraulic models to aid the design of hydraulic engineering works of all types.

One of the Karlsruhe studies built and tested in 1913 and 1914 was a 1:50 scale model of a floodwater bypass for the Pegnitz River in Nuremburg. The bypass had a streamlined inlet leading to a long culvert whose invert (bed) was set below the river bed. There is no mention in reference 4 of how the inlet and similar outlet were designed and it is likely that it was done intuitively. The outlet had some losses but they were much lower than those of a standard culvert. The culvert was never built but the model data was made available.

It is likely that Prof. McKay designed the Redcliffe culvert to be similar to the Rehbock model. He used to tell his students doing their MSc coursework that he was amazed by the extremely low losses in the Redcliffe model, much lower that he had expected. He must have spent considerable time working out the mathematical design method to ensure that ensuing structures had this desirable very low loss characteristic. In fact it wasn't till after several more models and graduate theses that a full theory could be published by Apelt in 1983.

The structure employed curved, streamlined fan structures that prevented any energy loss due to the excessive turbulence encountered with headwalls perpendicular to a conventional culvert. McKay modeled the structure in the

labs of the University of Queensland and extrapolated its design to the structure that now exists at Humpybong Creek today. To date the region has not been subject to flooding despite numerous extreme rain events which indicate the successful performance of the design. In addition to this, significant cost savings were achieved in its construction. A conventional culvert, which would experience shallow, sluggish flow with little acceleration, would have had to have been 150m wide and 30m long to achieve the same flow-rate of 26 cumecs. The costs involved would have been prohibitive and the flooding of the swampland would not have been alleviated.

The Redcliffe MEL culvert is recognized as a world first in hydraulic engineering and has since been the basis of numerous replications throughout Australia, the USA, UK and Canada. Prominent examples of these, whose descriptions can be found in the referenced research material, include the culverts built by Cottman in 1974 throughout the Shire of Stanwell, Victoria, after discovering McKay's paper in 1974, as well as many of MEL culverts built beneath the South-East Freeway in Brisbane in 1970-71 to reduce the spans of the bridges, and therefore the costs of the overall project.

It should also be noted that the control weir situated at the inlet lip of the Redcliffe MEL culvert is in fact another hydraulic engineering world first in being the first minimum energy loss weir. The claim is usually associated with the more prominent Clermont weir (QLD, 1963) in being the first large structure of its kind but is not the subject of engineering significance being recognised in this submission.

Listings: No listings have been found on either the Queensland Heritage Register, or the Australian Heritage Database.

ASSESSMENT OF SIGNIFICANCE:

Historic Phase:

The construction of the MEL culvert began and finished in the late 1950s to the early 1960s. In 1959 Redcliffe was officially recognized as a city when Princess Alexandra presented Redcliffe with a Royal Charter from Queen Elizabeth II during her visit to the Peninsula. Redcliffe had also become a tourist hub for people who wished to access its sheltered beaches and the surrounding islands of Moreton Bay. It could be argued that the local authority wished to eliminate the flooding problem experience by the stagnant marshes of the peninsula to meet the expectations of its newly found recognition as a progressive corner of South-East Queensland.

Historic Association:

The Redcliffe MEL culvert was designed by Dr Gordon McKay of the University of Queensland in Brisbane. McKay was fundamental to the progress of hydraulic engineering with his world first innovative techniques in reducing energy losses in hydraulic structures. His research conducted at the labs of UQ have become the fundamental theories upon which all subsequent MEL structures in both a national and global sense are based.

Creative or Technical Achievement:

The technical achievement of the Redcliffe MEL culvert is inherent in its recognition as being a world first for MEL structures. The absences of upstream afflux as well as the minimization of the throat width by means of streamlining the inlets/outlets and depressing the bed profile to produce near-critical flow were ground-breaking achievements in the field of hydraulic engineering. The obvious costs savings implicit in constructing and bridging the 5m wide MEL culvert in lieu of 150m wide conventional culvert demonstrate the significance of this innovation. Reference should be made to Apelt (1983), and Cottman et. al. (1990) for an in depth guide to the theory behind the design of these structures.

Research Potential:

The successful operation of the culvert during extreme rain events over the past 50 years, and its continuing use today, demonstrates the importance of strict adherence to the fundamental laws of open channel flow and fluid dynamics during design and construction. Observations of the culverts performance during flood events allow engineers to further refine the design technique of these structures. Professor Colin Apelt (1983) conducted inspections of a number of MEL culverts in a similar fashion which have subsequently helped progress the design of these structures e.g. the need for drainage in the depressed throat bed to prevent stagnant water after a storm event.

Social:

The social significance of the culvert has been addressed within the criteria of 'Historic Phase'. The argument made is that the construction of the MEL culvert to replace the marshy depression that linked the Humpybong catchment tributaries to Central Moreton Bay was an effort to meet the expectations of the new city's recognition as a progressive corner of South East Queensland.

Rarity/Representativeness:

At the time of construction, the Redcliffe MEL culvert was unique. Today is it one of hundreds of MEL structures concentrated along the East coast of Australia. It represents a fine example of a successful culvert capable of accommodating flows at, and slightly above, the designed flow rate. It is an example of a situation where significant cost savings were made in the bridging of the culvert due to the reduced width of the throat. It is also representative of the benefits of concrete-lined culverts. Numerous MEL culverts have natural profiles at the inlets and outlets. Problems have arisen in some of these circumstances due to the roughness factor of the outlet beds not being accounted for in the initial design calculations. This can lead to a downstream boundary condition that can potentially create a hydraulic jump in the throat. Keeping the inlet and outlet profiles concrete lined ensures that roughness does not become a problem.

Integrity/ Intactness:

The Redcliffe MEL culvert remains intact after almost 50 years of operation.

STATEMENT OF SIGNIFICANCE:

The Redcliffe Minimum Energy Loss Culvert, or Humpybong Creek, is of unique technical significance to the nation and more importantly the entire hydraulic engineering industry. The minimum energy loss culvert was envisioned by Dr G. R. McKay from the University of Queensland in Brisbane after he was confronted with solving the problem of decking the marshy depression which linked the Humpybong catchment tributaries with Central Moreton Bay. A solution was required that would minimize upstream afflux to prevent flooding of the river banks. The solution also needed to be economical by reducing the width of culvert that would need to be bridged. McKay developed a model which employed streamlined wing walls and fan shaped aprons as the inlets and outlets, preventing any head loss and associated upstream afflux. These converged into a narrow throat which had a depressed bed profile, the idea being that during a storm event the creek would be accelerated through the culvert at what is known as a 'critical' flow rate. After the obvious advantages of the model were realized, construction of the Redcliffe Minimum Energy Loss Culvert began, with construction being complete in 1961. This Australian breakthrough presented a world-first in the field of hydraulic engineering. Since its inception, hundreds of MEL structures have been built throughout the East Coast of Australia to meet the challenges of torrential rainfall events and minimal gradients that are characteristic of so many catchment areas in the region. Huge construction cost savings have been documented for a number of these projects when compared with the exhaustive requirements of conventional culvert design. The importance of this 'minimum energy loss' concept has also gained international recognition with interest being expressed from the USA, UK, and Canada.

Assessed Significance: National Engineering Heritage Landmark

Images: Refer to Appendix A.

References:

1. **Apelt, C J, (1983)** ***Hydraulics of Minimum Energy Culverts and Bridge Waterways*** Vol. CE 25, No. 2, IEAust.

Chanson, H, ***Minimum Energy Loss Structures in Australia: Historical Development and Experience*** 12th National Engineering Heritage Conference, IEAust.

Cottman, N H et. al., (1990) *Bridges and culverts reduced in size and cost by use of critical flow transitions* Part 1, Institution of Civil Engineers.

Rehbock, T H, (1926) *Das Flussbaulabatorium der Technischen Hochschule in Karlsruhe* Berlin, VDI-Verlag GMBH.

APPENDICES

Appendix A: Locality Plan
Appendix B: Images
Appendix C: Humpybong Creek Drainage Report
Appendix D: Approval of Plaquing by Owner

Appendix A – Locality Plan

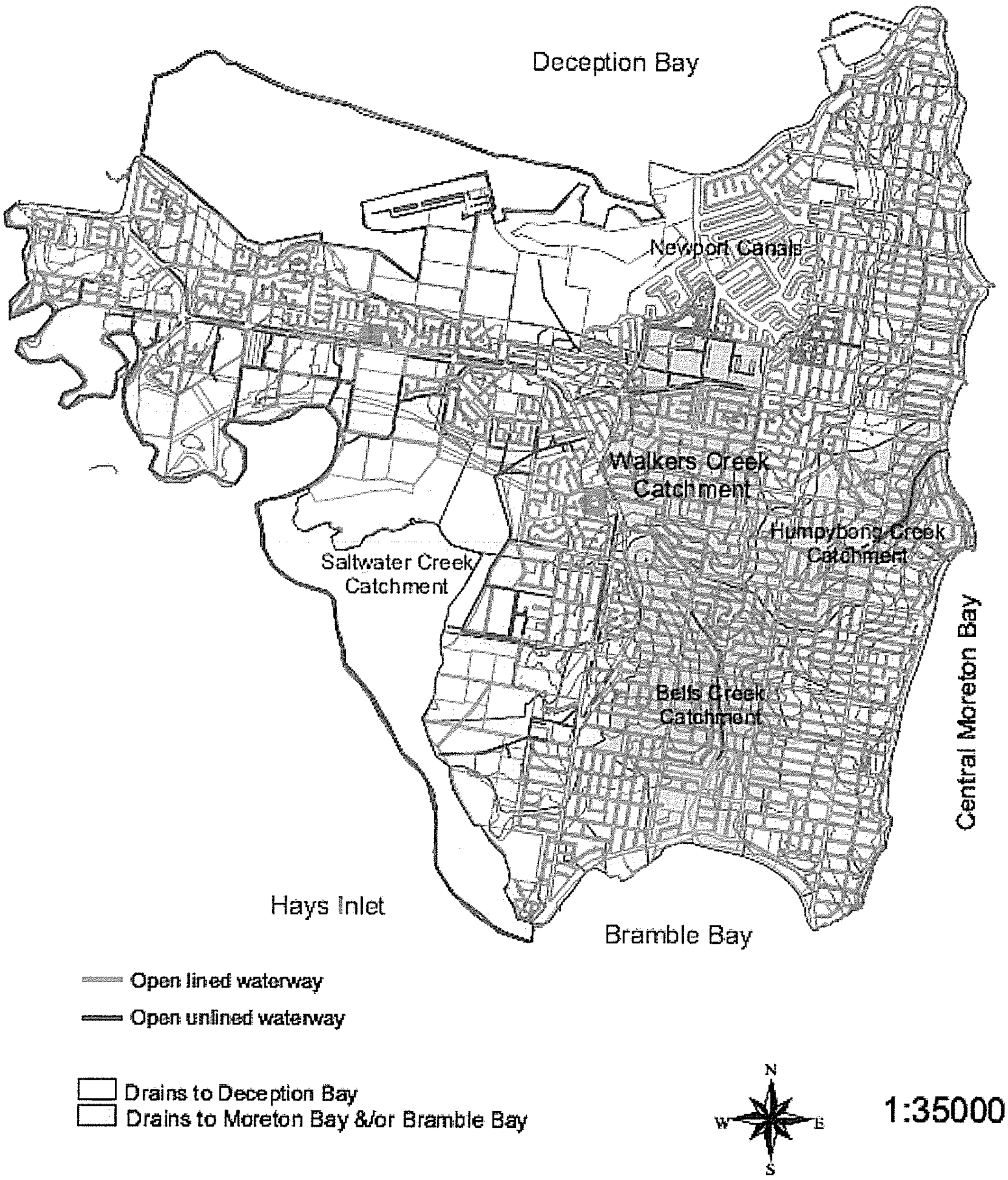


Fig 1. Catchments on the Redcliffe Peninsula. (Courtesy of the former Redcliffe City Council, now part of Moreton Bay Regional Council).

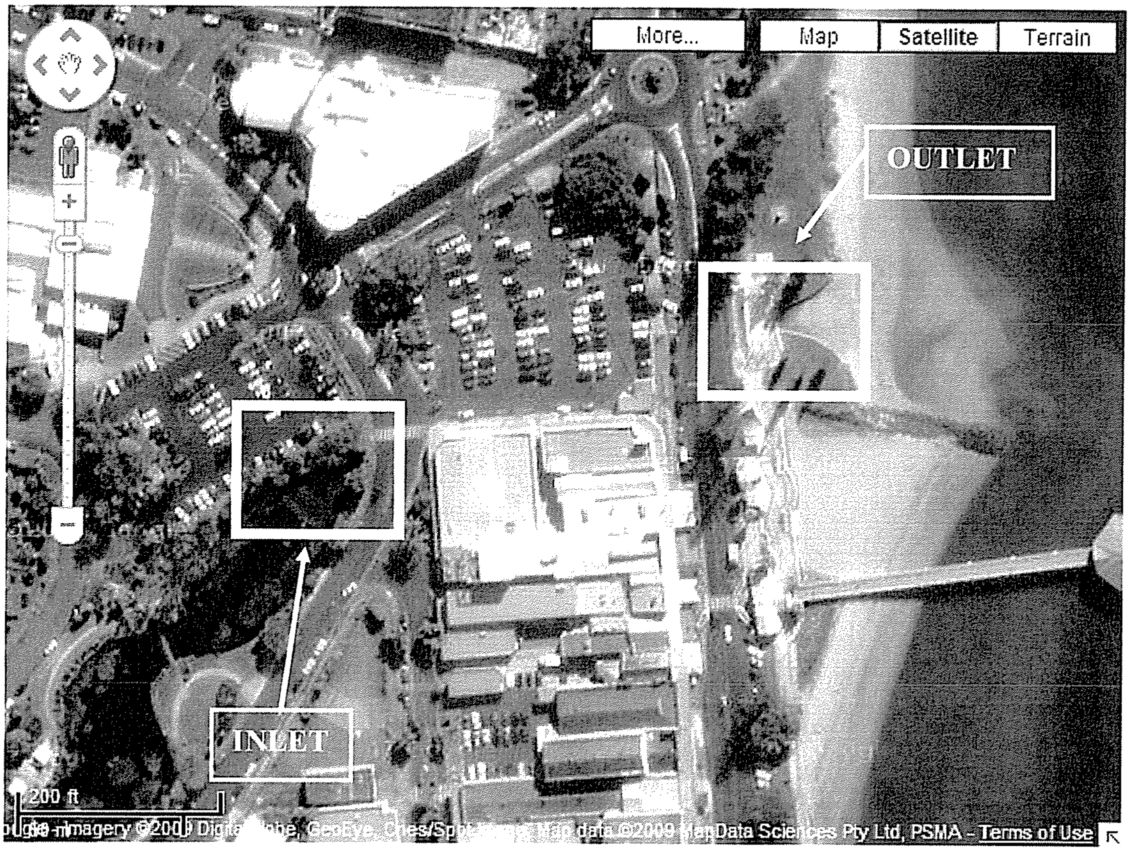


Fig 2. Arial photo of Humpybong Creek. (Courtesy of Googlemaps.com)

Appendix B – Images

Fig 3. Humpybong Creek before the 1961 construction of the MEL culvert. (Redcliffe Library Historical Photos No. 416).

Fig 4. Humpybong Creek after the 1961 construction of the MEL culvert. (Redcliffe Library Historical Photos No. 54).

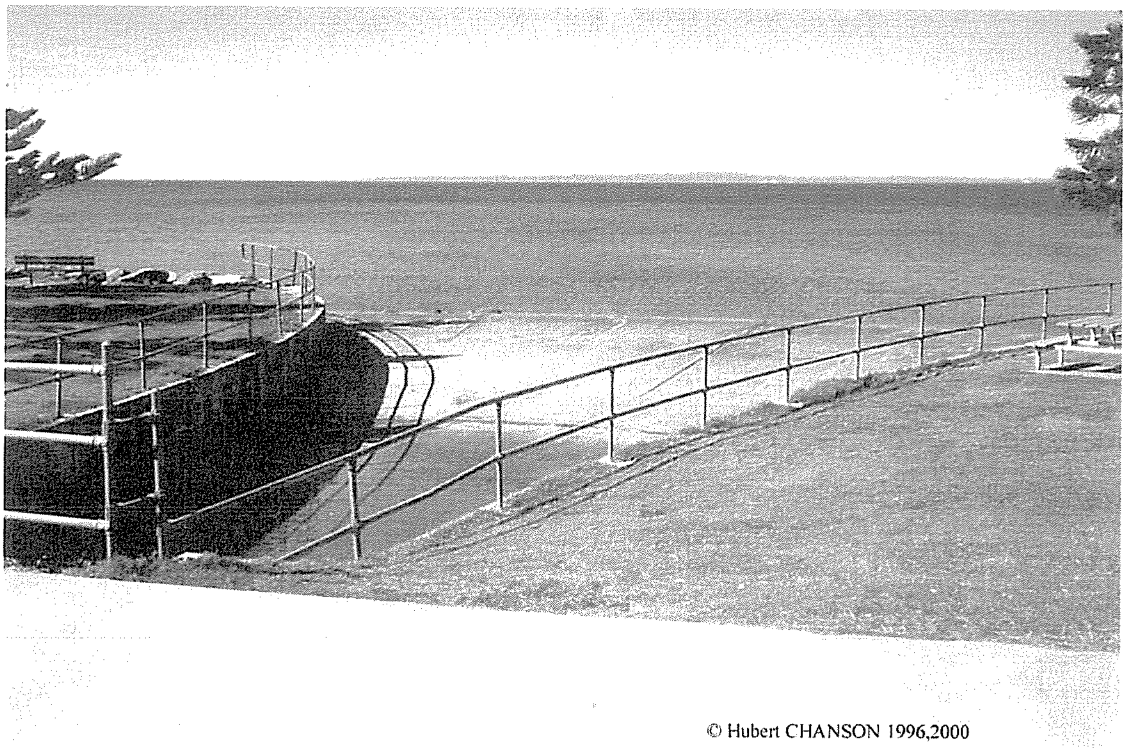


Fig 5. Outlet of Redcliffe MEL culvert into Central Moreton Bay. (Courtesy of H. Chanson, 1996, 2000)

Appendix C – Humpybong Creek Drainage Report

UNIVERSITY OF QUEENSLAND

DEPARTMENT OF CIVIL ENGINEERING

HUMPYBONG CREEK DRAINAGE OUTFALL

FEBRUARY 1961

Telephone : 7 2021

University of Queensland
ST. LUCIA, BRISBANE.

DEPARTMENT OF CIVIL ENGINEERING

REPORT

ON

HUMPYBONG CREEK DRAINAGE OUTFALL

FOR

REDCLIFFE CITY COUNCIL

This investigation was commenced by Dr. G. R. McKay at the Hydraulic Experiment Station, St. Lucia. The model tests were carried out and the final design determined under the direction of Dr. C. J. Apelt.

J. H. Lavery
(J. H. Lavery)
Professor of Civil Engineering.

20th February, 1961.

Personal copy of C.J. Apelt

INTRODUCTION:

The development of the main Redcliffe centre has been such that Humpybong Creek physically divides the town. To the North and West are the Public Buildings, such as the Town Hall, Library, Post Office, Police Station, R.S.L. Hall, C.W.A. Hall, the proposed Festival Hall and, further afield, the Showgrounds, and a considerable number of houses. The creek flows almost North before entering the sea, isolating the main shopping centre to the South of the outfall (Figure 5).

The area between Creek Street and Creek Esplanade is a mass of weed and unkempt grass on rough, uneven banks, with unattractive water held at a low level by a small weir built to prevent ingress of the sea water.

The proposals of the Redcliffe City Council involved a multi-purpose improvement. It was proposed to culvert the Creek for a considerable length at the outfall, and to dam up the creek to form a lake. Thus -

(1) The physical division of the City would be eliminated.

(2) The parking problem would be somewhat alleviated. Redcliffe, in common with most other towns, suffers a severe parking shortage near the shopping centre. Redcliffe is a popular family holiday resort and in summer the situation becomes impossible, as the summer visitors drive to the centre to buy essential supplies. The area reclaimed over the culvert would provide considerable convenient parking. The area would be equally convenient for the proposed Festival Hall and the City's Public Offices.

(3) The lake surrounded by a grassed and treed area would provide a delightfully cool place of relaxation, easy to maintain, in the heart of this popular and busy City.

The difficulty lies in the design of the culvert. Existing approaches to the proposed parking area determine the level of the area at 8.0 or 8.5 ft. above State Datum.

Equally a flood level at the entrance to the culvert of more than 8.0 ft. above Datum would cause serious inconvenience and damage in the existing surrounding shop and business property.

It has been found from bitter experience that storm culverts discharging below high water ordinary spring tides quickly pack with sand during no-flow periods and fail in subsequent storms. Furthermore, it is essential that sea water be excluded from the storm drains to avoid the decay of vegetable matter and the resulting nauseating stench. This fixes the downstream invert of the culvert at 3.5 (min.) ft. State Datum.

The catchment area of Humpybong Creek is a rapidly developing urbanised area and it is estimated that 950 cusecs would be a reasonable design flow when the area is fully developed.

The minimum water level in the proposed lake would have to be 5.25 ft. State Datum to give a reasonable water area.

To satisfy these conditions, it was estimated that at least five 6 ft. wide culverts would be required, each costing about £17,000 - a total of £85,000 - an amount which the City could not afford in its present state of development.

Alternative proposals, such as using the proposed parking area as an emergency flood relief, proved abortive owing to the hopelessly inefficient flow section which could be attained. To place fewer culverts now, adequate to deal with the present flow, to be later increased as the urbanisation of the catchment increased, made the present work possible, but the ultimate scheme would be far more costly and inconvenient. Also, there would be a period fraught with danger when the catchment had developed, but the culverts not yet increased to adequate size.

The Civil Engineering Department of the University of Queensland was asked to investigate the problem to see if there was a practical solution. During discussions the problem resolved itself into how to take the 950 cusecs down into an economically shaped culvert under the proposed car park and lift it again above high tide. This conception of the problem led away from the standard uniform flow design of culverts to that of non-uniform flow conditions.

It was considered that the City could afford an 18 ft. culvert (the cost of series or a simple culvert is much the same to this size); a preliminary calculation was made on this size on a uniform energy grade from an upstream level of 8 ft. State Datum. This calculation showed the method offered a possible solution.

As the design basis is rather arbitrary, a model was built to prove the calculations and to determine details not calculable and the most economic layout.

In general, the water flows over the wide retention weir of the lake down a smooth, converging slope to a uniform channel under the car park. At the outlet the water is taken up a smooth slope with diverging sides and over a weir just above high tide. Throughout, the energy is conserved as far as is practicable, the design depending essentially on conversion of velocity energy to potential energy and vice versa.

DETAILS OF MODEL:

The model was constructed outdoors in cement mortar at the University's Hydraulic Laboratory at St. Lucia, Brisbane. An undistorted scale of 1 in 12 or 1 ft. to the inch was adopted. Froude Law similarity was assumed since free surface flow under the action of gravity occurred in the model. The model surfaces were finished as smoothly as possible, so that the effect of surface roughness would not be excessive.

Designating the ratio of prototype to model linear dimensions as L_r, the relevant model scales were given by the Froude Law as follows:-

Length L_r - 1 in 12; Velocity $L_r^{\frac{1}{2}}$ - 1 in 3.46.

Discharge $L_r^{5/2}$ - 1 in 1200; Roughness (Manning's "n") $L_r^{1/6}$ - 1 in 1.5.

Thus the model discharge, to represent the design discharge of 950 cusecs, was 0.79 cusecs and, assuming that the roughness of the concrete surface of the prototype was 0.015, then the model roughness required was about 0.01, which should be obtainable with the smooth surface of the model.

Water was supplied to the model by pumping and the discharge was measured by means of a V-notch weir mounted in a brick tank at the upstream end of the model. Water levels were measured, using pointer gauges mounted at various locations on the model.

Portions of the completed model are shown in photos 1 and 2.

MODEL TESTS:

The first model was built to a theoretical design assuming a friction loss from traditional channel design and a uniform energy grade from inlet to outlet weir. Numerous modifications were made to improve flow variations from the theoretical until the final design, detailed herewith, was attained.

DETAILS AND OPERATION OF THE PROPOSED OUTFALL STRUCTURE:

The layout and dimensions of the final design are shown on Figure 4. It consists of three main sections, an inlet weir and transition, a section of straight channel with a single bend, and a flared outlet transition. The unusual shape of the outlet has been evolved to conserve the velocity energy of the water and to reconvert velocity energy to potential energy.

Two regimes of flow occur in the outfall. At low discharge - up to 700 cusecs - a hydraulic jump forms in the inlet transition downstream of the inlet weir. Flow in the main channel is subcritical. In the outlet transition the expanding flow remains subcritical until it flows over the outlet weir at critical depth. Under these conditions, water levels in the outfall are controlled by the outlet weir and the channel roughness. The water level in the lake upstream of the inlet weir is dependent only on the characteristics of this weir. The water surface in the channel is very

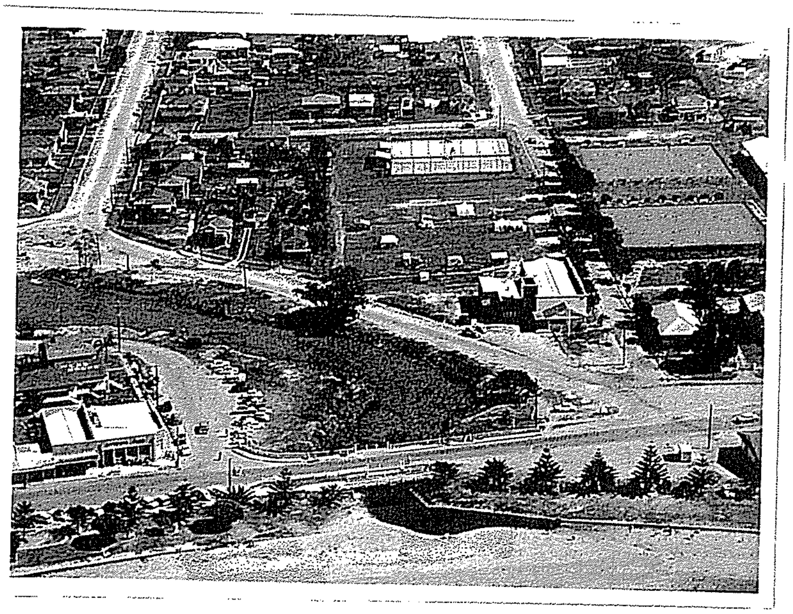


Photo 1.
View of Humpybong Creek Outfall.

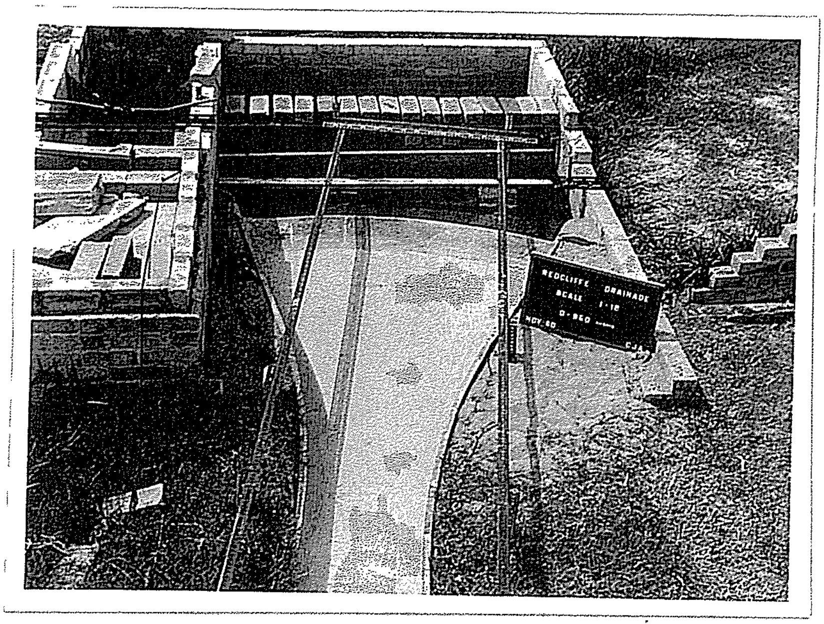


Photo 3

Model - Inlet

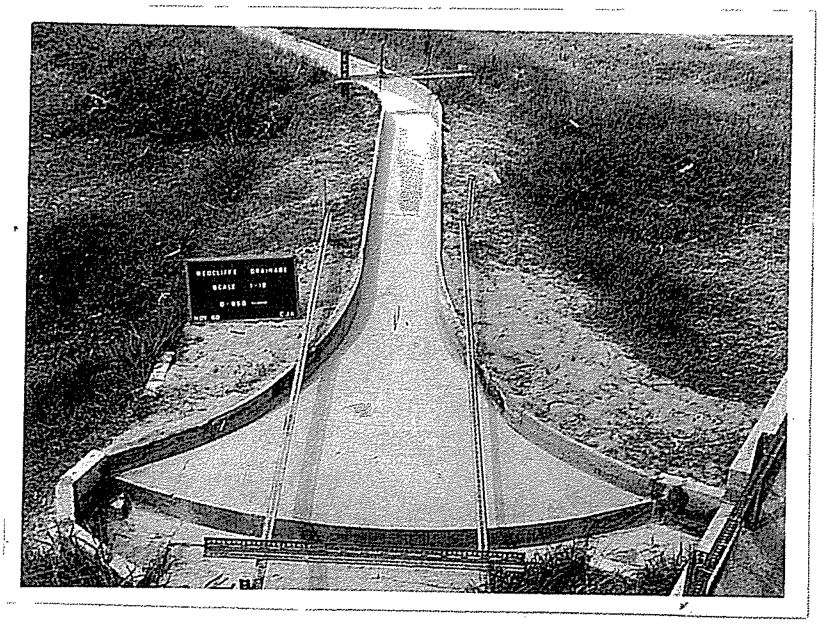


Photo 4

Model - Outlet

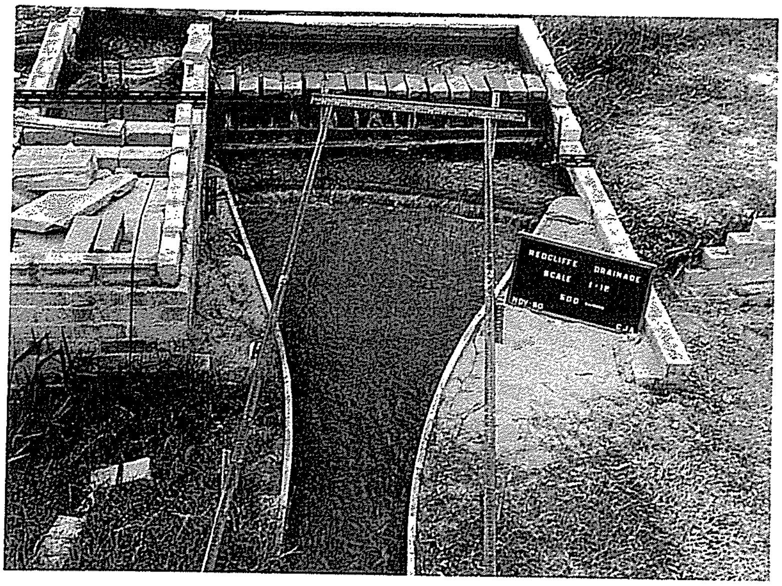


Photo 5

Inlet - 500 cusecs

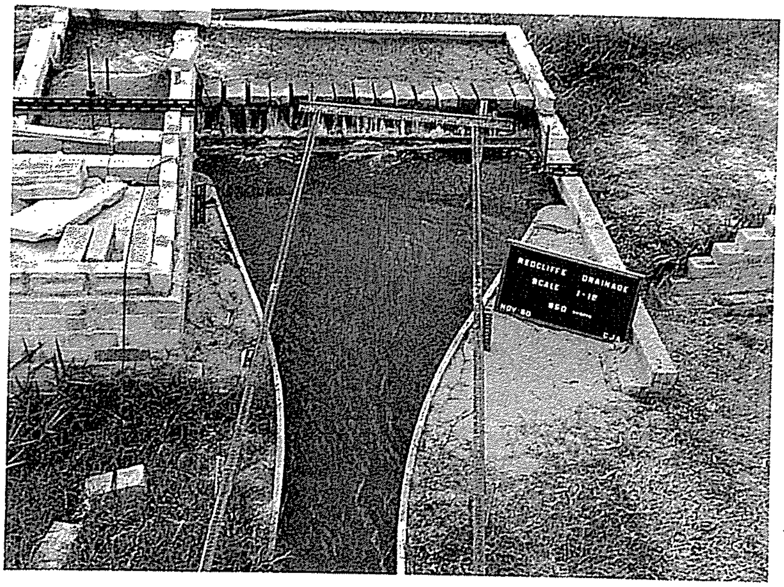


Photo 6

Inlet - 950 cusecs

Photo 7
Outlet - 500 cusecs

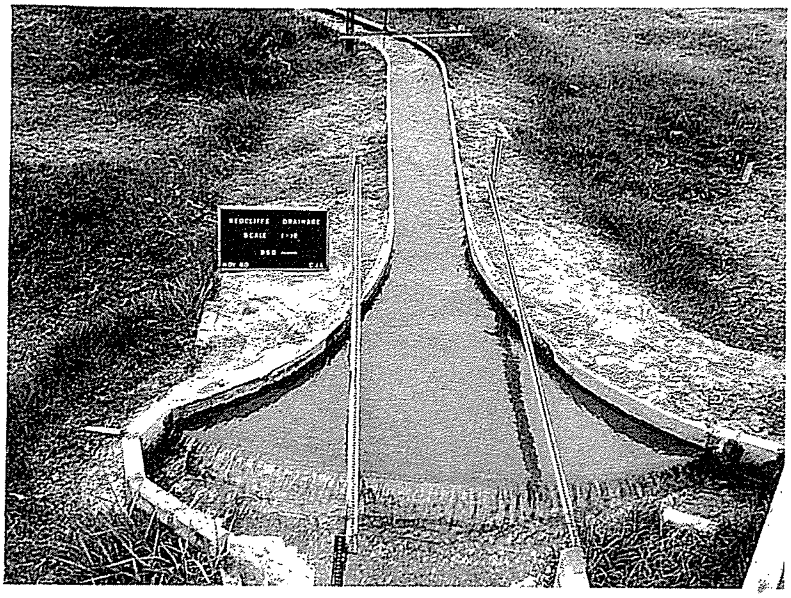


Photo 8
Outlet - 950 cusecs

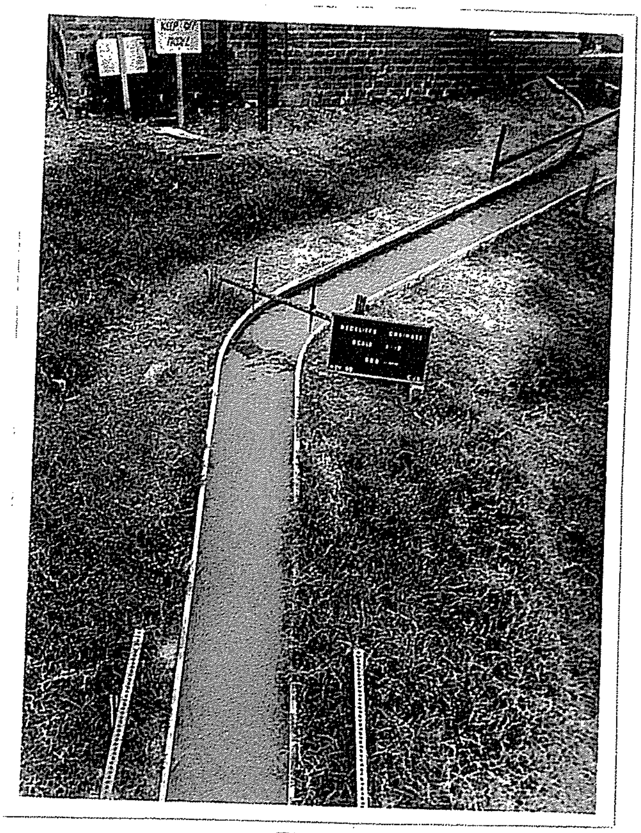


Photo 9
Channel - 500 cusecs

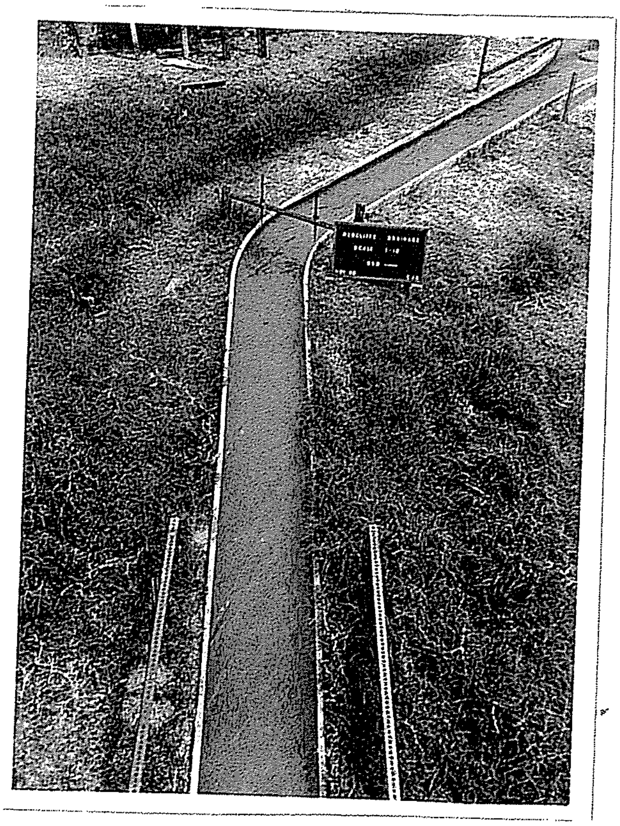
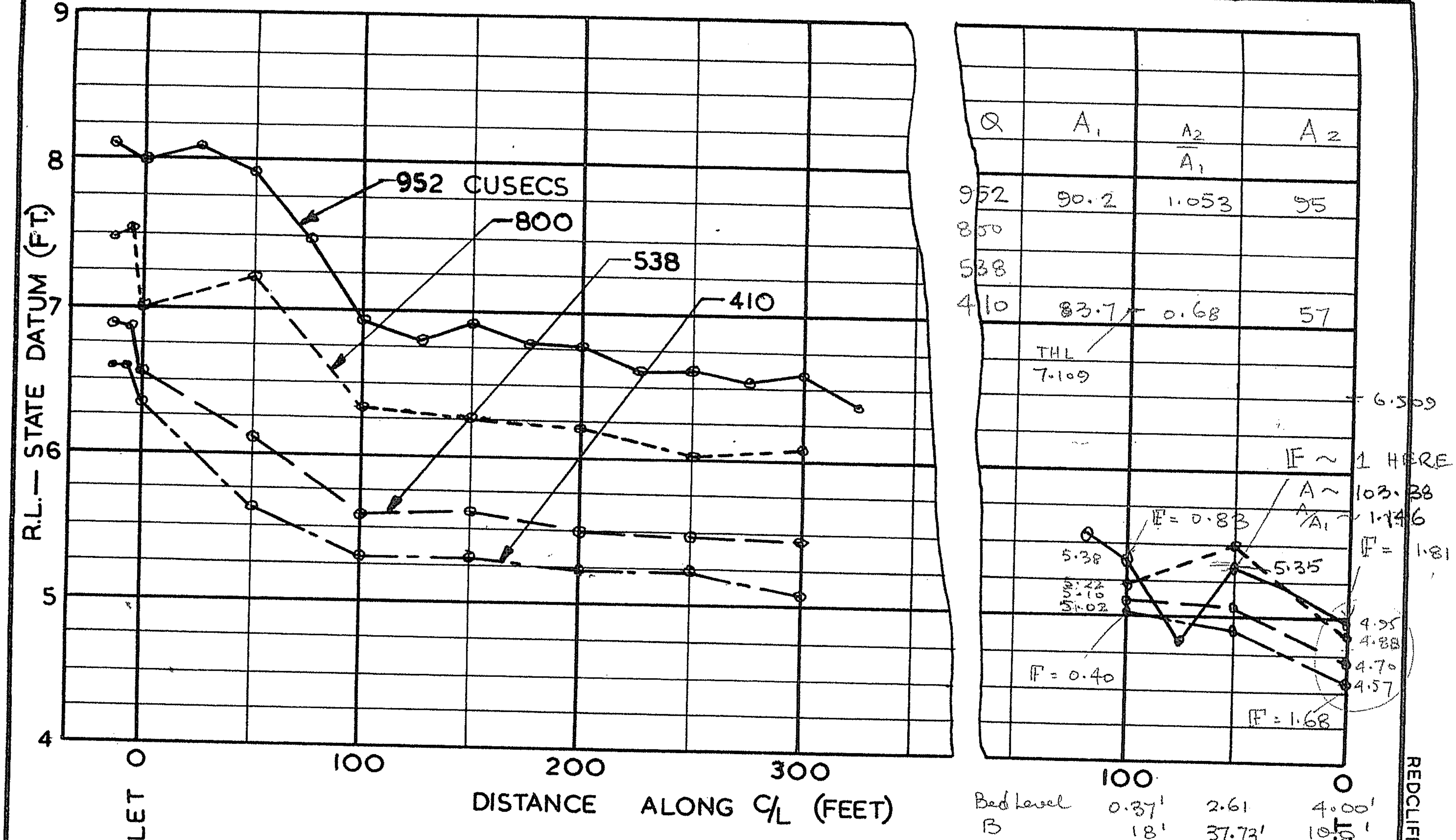


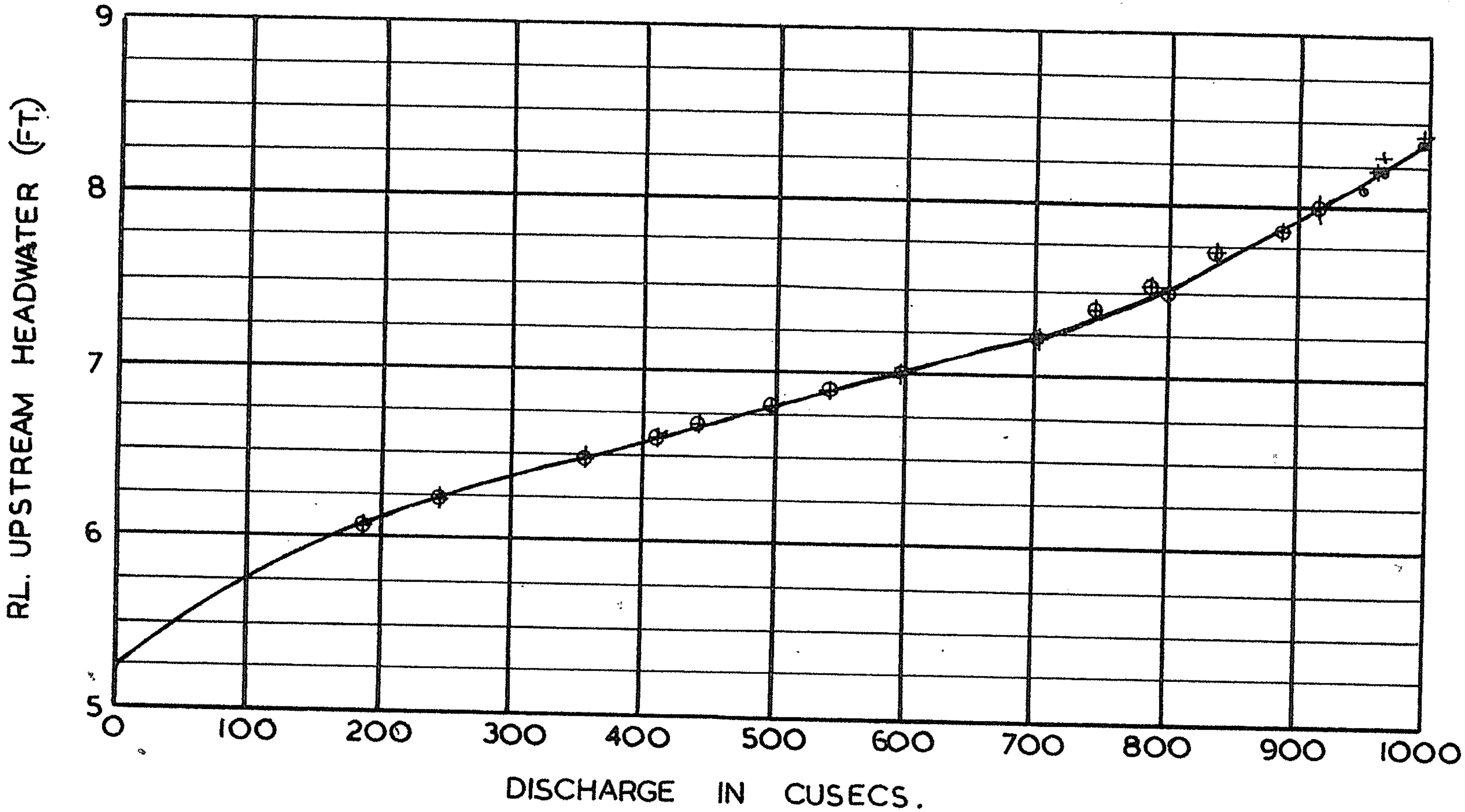
Photo 10
Channel - 950 cusecs



WATER SURFACE PROFILES

FIGURE 1.

REDCLIFFE CITY COUNCIL



NOTES.

⊙ MEASUREMENTS AT C/L, 14' U/S OF CREST.

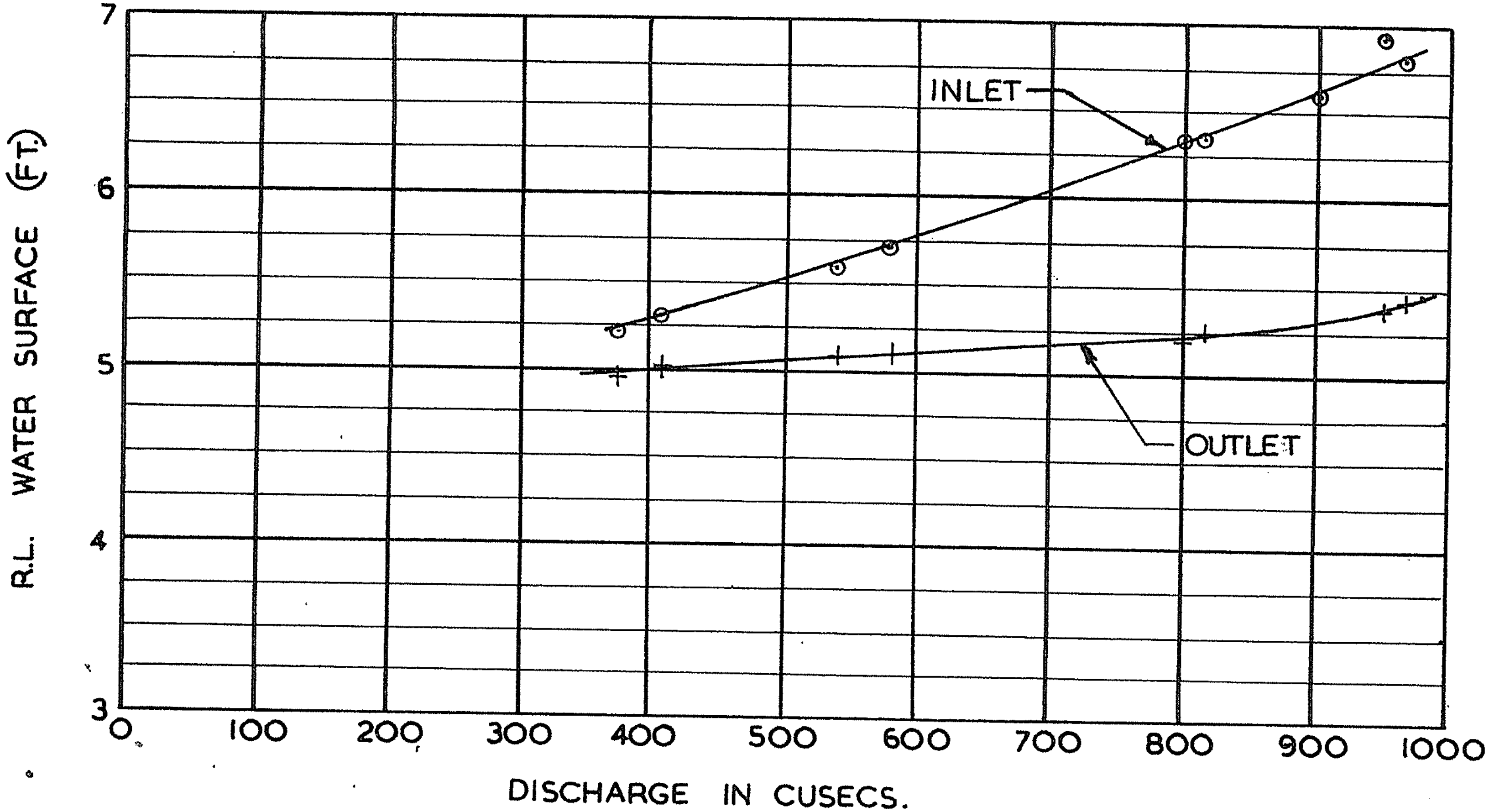
+ MEASUREMENTS 6' U/S OF LEFT ABUTMENT.

R.L. OF INLET WEIR CREST = 5·25'.

R.L. OF MAXIMUM DESIGN HEADWATER = 8·00'.

INLET RATING CURVE

FIGURE 2.



NOTES.

⊙ MEASUREMENTS 100′ D/S OF INLET

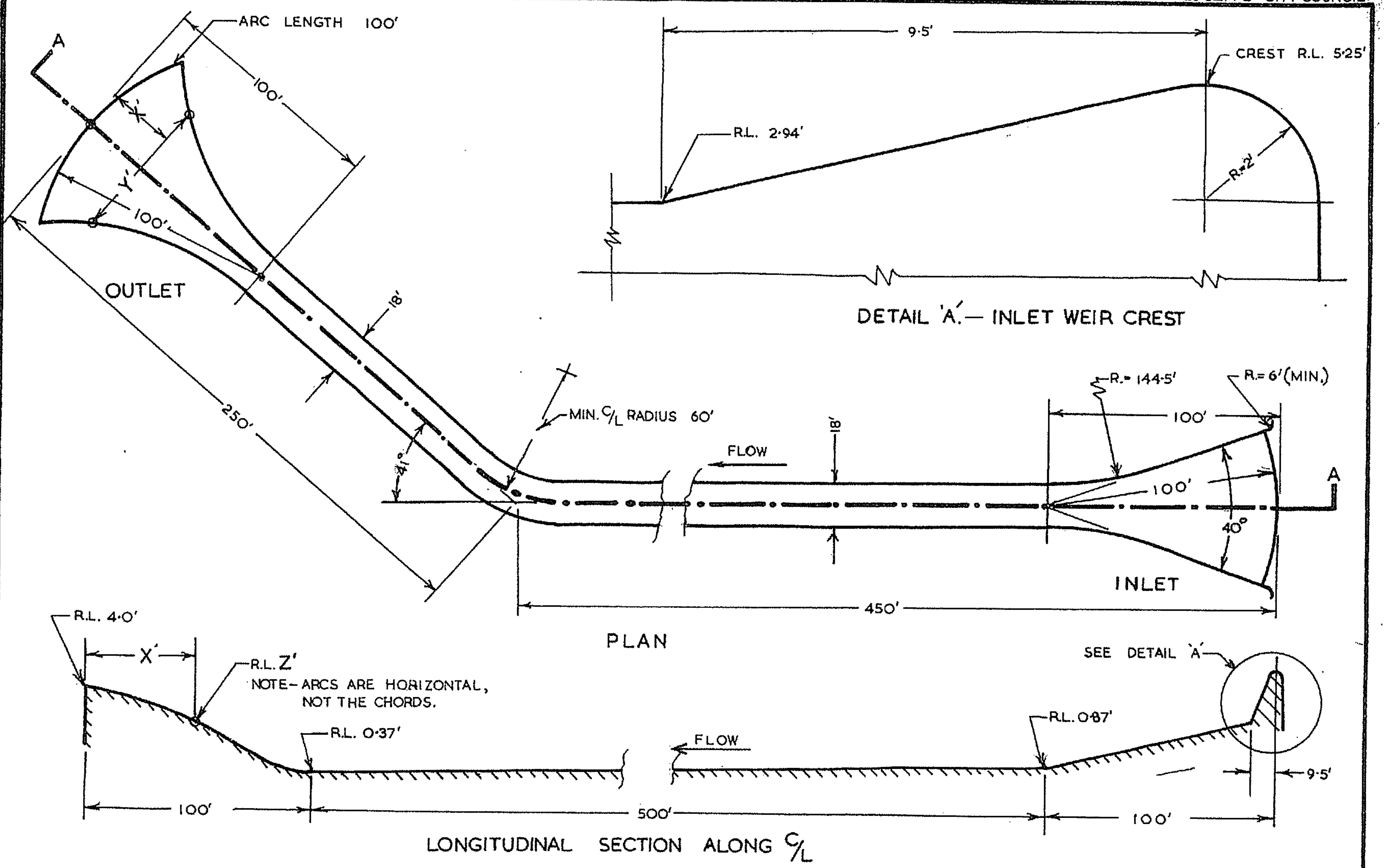
+ MEASUREMENTS 100′ U/S OF OUTLET

ALL LEVELS TO STATE DATUM

CHANNEL RATING CURVES

FIGURE 3.

REDCLIFFE CITY COUNCIL



OUTLET TRANSITION
(LEVELS TO STATE DATUM)

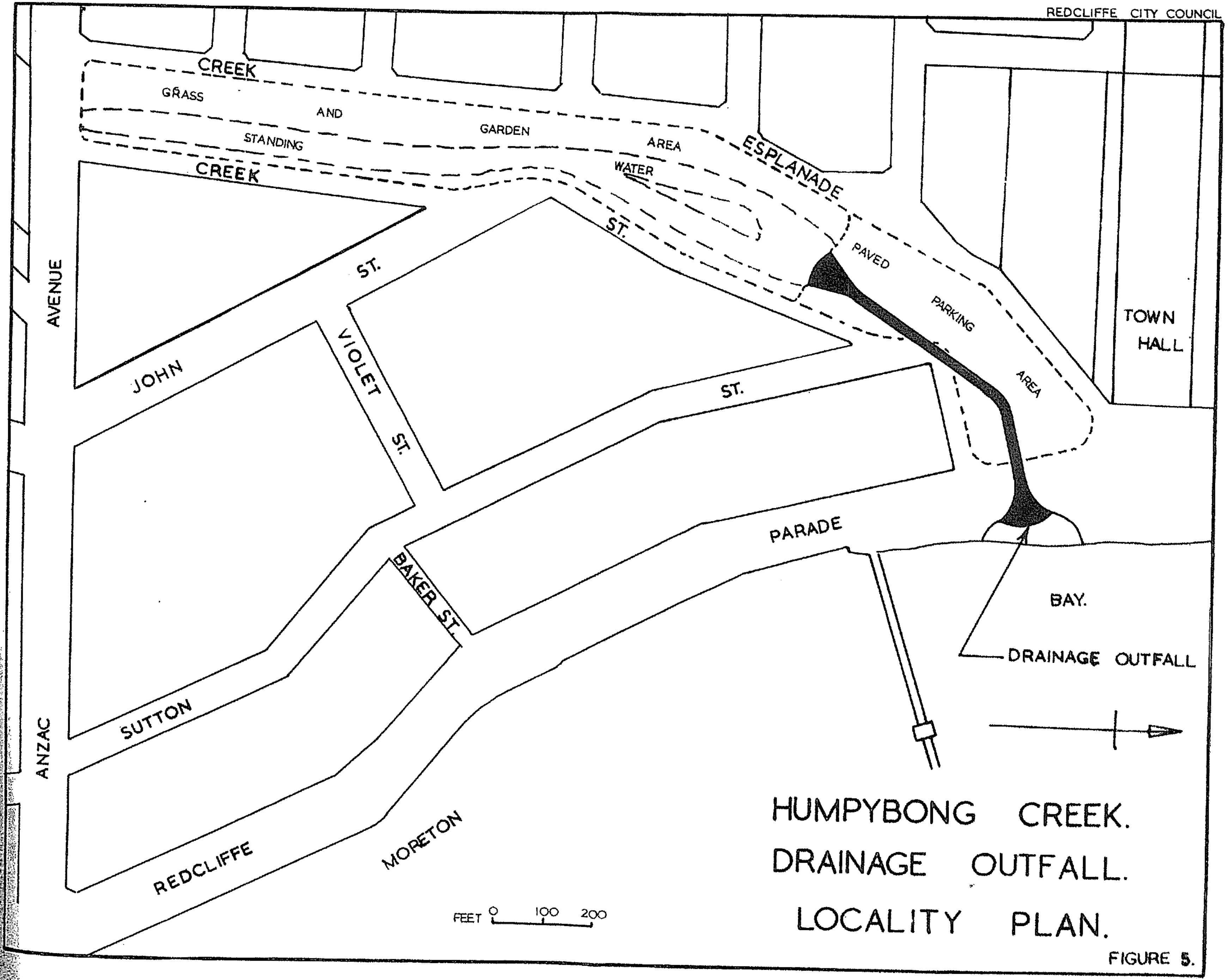
X	0	12·2	25·0	37·5	50·0	62·5	75·0	87·5	100·0
Y	–	95·6	65·0	47·8	36·2	28·0	22·0	18·5	18·0
Z	4·00	3·81	3·52	3·13	2·61	1·98	1·17	0·66	0·37

ARC 100
MIN θ
37.73
39.8°

HUMPYBONG CREEK DRAINAGE OUTFALL GENERAL ARRANGEMENT

FIGURE 4.

REDCLIFFE CITY COUNCIL



HUMPYBONG CREEK.
DRAINAGE OUTFALL.
LOCALITY PLAN.

FIGURE 5.

Appendix D – Approval of Plaquing by Owner

Moreton Bay
Regional Council

Phone: (07) 3480 6233
Fax: (07) 3881 3204
Our Ref: A4411140
Date: 6 October 2010

The Chairman
Engineering Heritage Australia (Qld)
Engineering House
447 Upper Edward Street
BRISBANE QLD 4000

Dear Sir,

Proposal for Award of an Engineering Heritage Marker for the Minimum Energy Loss Culvert, Humpybong Creek, Redcliffe

Moreton Bay Regional Council is cognisant of the heritage value of the culvert under Redcliffe Parade at the Humpybong Creek outfall to Moreton Bay.

This culvert was the first constructed to the innovative design by the University of Queensland's Professor Gordon McKay. The design principles have since been extensively adopted for culvert construction throughout Australia and abroad.

Consequently, Council is pleased to support the nomination by Engineering Heritage Australia (Qld) for an Engineering Heritage Marker to be awarded to this innovative and historic construction.

For further information in relation to this matter, please don't hesitate to contact me on the number referenced above.

Yours faithfully,

Anthony Martini
Director
Engineering, Construction and Maintenance